Thermal Performance of Wall & Roof – Efficiency of Building Materials

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Abstract: Thermal condition of outdoor & indoor can be measure for the comfort level of human. A human can control the inside comfort level by thermal materials, but outdoor comfort level is not control by human, because man-made is things can only be controlled by the human. Indoor thermal conditions up to a certain extent can be improved by a judicious selection of building components, optimum orientation & proper selection of shading devices. Now-a-days such man-made materials are available which can control the climate. This paper contains the values of the different materials to control & perform better for the thermal performance in architecture & planning fields.

Keywords: Sustainable, Thermal Performance, Material efficiency, climatic zones, Thermal Conductivity

1. Introduction

Sustainability is the need of time; the word may be used in buildings, towns, cities, traffic and transport etc. Sustainability is the term used for technology and methodology used for saving and conserving energy, it may be in the form of fuel, electricity or other means. While designing the sustainable building, understanding of thermal performance of roof and wall is important. The main aspects of the design of thermally comfortable buildings are minimizing the flow of heat & reducing wall & roof surface temperature under summer conditions. Up to certain extent indoor thermal environment can be controlled by proper design & planning of building sections in relation to the climatic conditions. In this building digest data on thermal performance of the building sections has been provided. This will enable the architects & designers to choose proper section & system to improve thermal environment in building.

2. Thermal Requirements

India is country with diversified climatic zones. Table-A represents the name of cities falls under different climatic zones. After that Method for calculation of overall heat transfer coefficient (U) has been used in illustrated at the end. The thermal conductivity of different building materials is shown in Table-B.

In earlier building digests the thermal performance of building sections were evaluated in terms of the parameter. 'Thermal Performance Index' (T.P.I.), in case of unconditioned buildings excess of peak inside surface temperature over 30 degree has been taken as the criterion & 08 degree temperature rise over this base temperature is taken as equivalent to 100 of T.P.I. Suitable criteria for rating & classification was also evolved & has been given referred building digests.

Table below listed out the names of cities in India according to climatic zones.

	<i>S.N</i> .	Hot & Arid	Hot & Humid	Warm &	Cold Zone
		Zone	Zone	Humid Zone	
	1	Agra	Ahmadabad	Cochin	Darjeeling
	2	Ajmer	Asansol	Dwarka	Dras
	3	Akola	Bhavanagar	Gauhati	Gulmarg
	4	Aligarh	Bhuj	Puri	Leh
	5	Allahabad	Bombay	Sibsagar	Mussoorie
	6	Ambala	Calcutta	Silichar	Nainital
	7	Bareilly	Calicut	Tezpur	Shillong
	8	Bikaner	Cuttack	Veraval	Simla
	9	Gaya	Dohad		Skardu
	10	Jabalpur	Jamnagar		Srinagar
	11	Jaipur	Jamshedpur		
	12	Kanpur	Madras		
	13	Khandwa	Madurai		
	14	Kota	Mangalore		
	15	Lucknow	Salem		
	16	Ludhiana	Midnapur		
	17	Nagpur	Nellore		
1	18	Neemuch	Patna		
	19	New Delhi	Rajkot		
	20	Roorkee	Ratnagiri		
	21	Sambalpur	Masulipatam		
	22	Sholapur	Surat		
	23	Umaria	Tiruchirapalli		
	24	Varanasi	Vellore		

Table-A: Some Representative Towns Under Hot & Arid,Hot Humid, Warm & Humid, & cold Zones

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Table B: Thermal Conductivity (K-Value) of Buildin	g
Fabrics at Medium Temperature	

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S.N.	Name of building Fabrics	Density	Mean	Thermal
		Kg/m3	Temp.	Conductivity
				K.Cal/hr/°CM
1	Brick	1820	45.6	0.697
2	RCC (Mix 1:2:4 by weight)	2288	42	1.360
3	Cement Mortar	1648	45.6	0.808
4	RCC Brick	1920	42.5	0.945
5	Lime Concrete	1446	41	0.628
6	Mud Phuska	1922	42	0.446
7	Brick Tile	1892	41	0.586
8	Cement Plaster	1762	42	0.620
9	Cinder Concrete	1406	43	0.590
10	Cellular Concrete	704	42	0.162
11	Foam Concrete-1	704	42	0.128
12	Foam Concrete-2	250	40.8	0.054
13	Window Glass	2350	59.5	0.701
14	A. C. Sheet	1520	44.1	0.240
15	Timber Various	720	41	0.124
16	Gypsum Board (with layer	939	41	0.035
	of Hessian Cloth)			
17	Vermiculite (loose)	264	42.0	0.059
18	Dolomite Brick	675	53.9	0.092
19	Crushed Dolomite	688	51.2	0.027
20	Thermocole	22	41	0.027
21	Foam Glass	160	41	0.047
22	Foam Plastic	24	29	0.027
23	Saw Dust	188	42	0.044
24	Soft Board	249	33	0.040
25	Wall Board	262 💪	37	0.046
26	Chip Board	432	35	0.058
27	Chip Board (perforated)	352	35	0.057
28	Particle Board	750	37.20	0.084
29	Coconut Pith Insulation	535	44.0	0.052
	Board			
30	Bartex Insulation Board	329	59.6	0.058
31	Jute Felt	291	37	0.044
32	Mineral wool slab	192	43.1	0.035
33	Crown Fiber Glass	32	40.1	0.032
34	G. I. Sheet	7520	50	52

Table C discuss about the quality performance are peak hours

Table-C: Quality Performance

		~ /		
Sl.	Peak Degree Hrs.	T. P. I.	Class	Quality Perform-
No.	$^{\circ}C$ above $30^{\circ}C$			ance
1	< 6°C	<75	Α	Good
2	$> 6^{\circ}C < 10^{\circ}C$	>75 <125	В	Fair
3	$> 10^{\circ}C < 14^{\circ}C$	>125 <175	С	Poor
4	$> 14^{\circ}C < 18^{\circ}C$	> 175 < 225	D	Very Poor
5	>18°C	>225	E	Extremely Poor

Table D discuss about the correction factors of Material,Surface finish, Shades in different climatic zoneslike HotDry, Hot Humid, Warm –Humid

SN	Description	Design	Hot-Dry	Hot-humid	Warm
		Factors			Humid
1	Material	Roof	1.0	0.95	0.92
		Wall	1.0	0.85	0.75
2	Surface finish				
	Roof	Dark	1.0	1.0	1.0
		Light	0.73	0.74	0.69
	Wall	Dark	1.0	1.0	1.0
		Light	0.79	0.77	0.75
3	Shade	Roof	1.0	1.0	1.0
		Wall	0.31	0.27	0.26

Table-E discuss about the Thermal Performance Index, U values & Overall Heat Transmission Value of different section and thickness of Walls (Hot Dry Climate)

Table-E: Thermal Performance Index & Overall Heat

 Transmission Value of Walls (Hot Dry Climate)

Sl.		Specifications		U	TPI	r
No.	Basic	Interior	Exterior	Kcal/m2h	Value (Clas
				$r^{\circ}C$		S
		Wa	lls			
1	7.5cm	-	-	3.379	231	Е
	brick					
	Panel					
2	7.5cm	1.8 Cm cement	1.8 Cm	3.077	198	D
	brick	plaster	cement			
	Panel		plaster			
3	7.5cm	7.5cm sundried	1.8 Cm	2.119	124	В
	brick	Brick+1.8cm	cement			
	Panel	mud Plaster	plaster			
4	7.5cm	Air space	1.8 Cm	1.579	101	В
	brick	+1.5cm	cement			
200	Panel	Sundried brick	plaster	1.057	100	
5	7.5cm	11.5cm	1.8 Cm	1.857	102	в
	brick	sundried Brick	cement			
	Panel	+1.8cm mud	plaster			
6	7.5.000	Air space	1.9 Cm	1.420	94	D
0	7.50m	All space	1.8 CIII	1.429	04	D
	Panel	Sundried brick	nlaster			
	1 and	+ mud Plaster	plaster			
7	11.5cm	1 8cm mud	18Cm	2 589	157	С
- >	brick	plaster	cement	2.307	107	Ŭ
	Panel		plaster			
8	11.5cm	11.5cm Mud	1.8 Cm	1.688	85	В
	brick	sundried	cement			
	Panel	Brick +1.8cm	plaster			
		mud Plaster				
9	11.5cm	1.8cm mud	1.8 Cm	2.130	119	В
	brick	plaster	cement			
	Panel	101	plaster			
10	23 cm	1.8cm mud	1.8 Cm	1.801	87	В
	brick	plaster	cement			
11	Panel		plaster	2.1.62	175	C
11	15.0cm	5 /	-	5.165	1/5	
. (Cono	/				
· /	Block	/				
12	15 0cm	1.8cm lime		2 020	161	C
12	stone	nlaster		2.720	101	C
1	block	Pruster				
13	20.0cm	1.8cm lime	-	2.668	132	С
	stone	plaster				
1	block	1				
14	30.0cm	1.8cm lime	-	2.187	89	В
1	stone	plaster				
	block	_				
15	25.0cm	-	-	1.43	79	В
	mud wall					

Table-F discuss about the Thermal Performance Index & Overall Heat Transmission of Roof Sections (Hot-Dry Climate

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Sl.		Specificat	ecifications		U TPI	
No.		-				
	Basic	Interior	Exterior	Kcal/m2	Value	Class
				$hr^{\circ}C$		~
1	10cm	1.50cm	9.0cm lime	2.221	134	C
	RCC	Plaster	concrete			
2	10cm	1.50cm	5.0cm mud	2.056	122	В
	RCC	Plaster	Phaska+5.0c			
			m Brick tile			
3	7.5cm	1.50cm	9.0cm lime	2.320	149	С
	cement	Plaster	concrete			
	Concrete					
4	11.5cm	1.50cm	7.5cm lime	1.977	132	С
	brick	Plaster	concrete			
	Panel					
5	5.0cm	-	15.0cm mud	1.069	89	В
	timber		Phaska+ Cow			
			dung Coating			
6	13.0cm	1.50cm	9.0cm lime	2.11	121	В
	RCC	Plaster	concrete			
7	7.5cm	-	12.0cm mud	1.881	126	С
	stone		Phaska	/	ALV	Ν.Ι
8	3.5cm	-	12.0cm mud	1.327	121	В
	brick		phaska	10	/	1
	Tile over		/		/	/
	wood		/	/		/
	rafter			/		/ /
9	7.5cm	-	12.0cm mud	1.748	104	В
	brick		phaska	/		
	Tile over		/			
	wood		1			
10	rafter		-			
10	15 cm	-	1.5cm cement	2.58	161	C
	brick		concrete			
	Tile over					
	wood		1			
	rafter		(1)			

Table-F: Thermal Performance Index & Overall Heat	i
Transmission of Roof Sections (Hot-Dry Climate)	

Table-G: discuss about Thermal Performance Index overHeat Transfer Coefficients of Slop Roofs

 Table-G: Thermal Performance Index over Heat Transfer

 Coefficients of Slop Roofs

Sl.	Basic Elements	Interior	U	T.	PI
No.		Lining along the Slopes	Kcal/m2hr °C	Value	Class
1	0.640 A.C. Sheet	-	4.24	378	Е
2	0.640 A.C. Sheet	Air space	0.932	104	В
		2.5cm			
		fiber glass			
3	0.32 G.T. Sheet		4.76	425	E
4	Country tile on bamboo		3.422	322	E
	matrix				
5	Mangalore tiles		4.419	390	E
6	7.5cm compressed straw boards		0.826	102	В

3. Correction Factor

The correction factor (F) for calculating T.P.I. values due to other climatic zones for unconditioned buildings were obtained & are shown in Table-D. The modified T.P.I. value can be obtained from the simple equation.

Corrected T.P.I. = $(T.P.I. - 50) \times F + 50$

3.1 Example

The Find the corrected T.P.I. values in Hot-Dry & Hot-Humid region for 7.5 cm brick panel (light color surface finish) with 1.75cm thick cement plaster on both sides. T.P.I. value from Table-E is 198 for the wall & correction factors are 0.79 & 0.77 (from Table-D).

1) Corrected T.P.I. in Hot-Dry region (Light colors)

- = (198 50) x 0.79 +50 = 166.92
- 2) Corrected T.P.I. in Hot-Humid Region

Similarly the effect of surface finish & shading can be calculated.

4. Inferences

It can be observed from Table-E that a layer of mud plaster can be used to reduce T.P.I. & U-values. The results also indicate that it is more effective when used on exterior surface. The thermal performance improves considerably with the increase in thickness of brick wall. It is also observed that cement concrete block & sand stone masonry are inferior to brick wall for the equivalent thickness. However, mod walls are better than brick wall. It may be noted from Table-E that an additional layer of 7.5 cm sundried brick wall & air space in between improve the thermal performance to a great extent. The increase in thickness of sundried brick from 7.5 cm to 11.0 cm further reduces the T.P.I. values from 101 to 84.

Thermal performance of roof without any insulation treatment does not satisfy the thermal requirements. It can be improved by additional treatment of insulating materials. A treatment of 5.0 cm to 7.5 cm of mud phaska on RCC & RBC improves the thermal performance considerably as may be observed from Table-F. On the type of insulating materials like foam concrete, thermocole, wood wool board can also be used. 2.65 cm thickness of insulating materials will be sufficient for these purposes.

It can be observed from Table-G, that the thermal performance of sloped roofs can be improved to a great extent, this surface as done in suspended ceiling.

5. Calculation of U-Values

The u-values can be calculated from knowledge of K-values of different materials, their thickness & surface coefficients. The K-values of different type of materials are given in Table-F. The formula for calculating U-values is:-

 $\label{eq:u} \begin{array}{l} U=1/RT=Ro+R1+R2+Ri\\ Where Ro=1/fo, Ri=1/fi \ , Ri=Li/k1 \ , R2=L2/k2\\ Where RT=Total Resistance offered in the materials.\\ fo=Outer surface coefficient. \end{array}$

- fi = Inside surface coefficient.
- L = Thickness of material.

K = Thermal conductivity.

One example of calculation U-values is given below:-

Example:

To calculate the U-value for a 20 cm thick brick wall, with 1.0 cm thick cement plaster on both sides:

K1 = 81.8 (plaster), K2 = 69.7 (Brick), K3 = 81.8 (plaster) Kcal/ hr cm^2 per cm. L1 = 1.0, L2 = 20.0, L3 = 1.0 cm, f1 = 8, fo = 19.42 R1 = L1/K1 = 1.0/81.8 = 0.0122R2 = L2/K2 = 20.0/69.7 = 0.2870R3 = L3/K3 = 1.0/81.8 = 0.0122Ri = 1/f1 = 1/8 = 0.1250R0 = 1/fo = 1/19.42 = 0.0515RT = 1/fo + 1/f1 + R1 + R2 + R3 = 0.4879 $U = 1/RT = 1/0.4879 = 2.05 \text{ Kcal/hr cm}^2$.

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6. Recommendations

From the data on thermal performance index & U-values presented in this paper can assess the relative performance of wall & roof sections. It will enable them to make proper choice of materials to obtain better indoor thermal conditions. These values refer to Hot-Dry climate. From the correction factors, the thermal performance rating can be calculated for other climatic zones.

By using these methods and materials the energy could be saved which will contribute to build a sustainable building. Properly selected material according to climatic zone will help in reducing the use of active means of cooling or heating.

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